LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

LLNL-CONF-683336

Snowball Modeling

P. Vitello

February 18, 2016

6th Annual JOWOG 9 Initiation Train SUBWOG Workshop
Los Alamos, NM, United States
May 14, 2016 through May 18, 2016

Unclassified

Snowball Modeling

6th Annual JOWOG 9 Initiation Train SUBWOG Workshop

LANL, Los Alamos, New Mexico

March 14-18, 2016

Peter Vitello

Lawrence Livermore National Laboratory

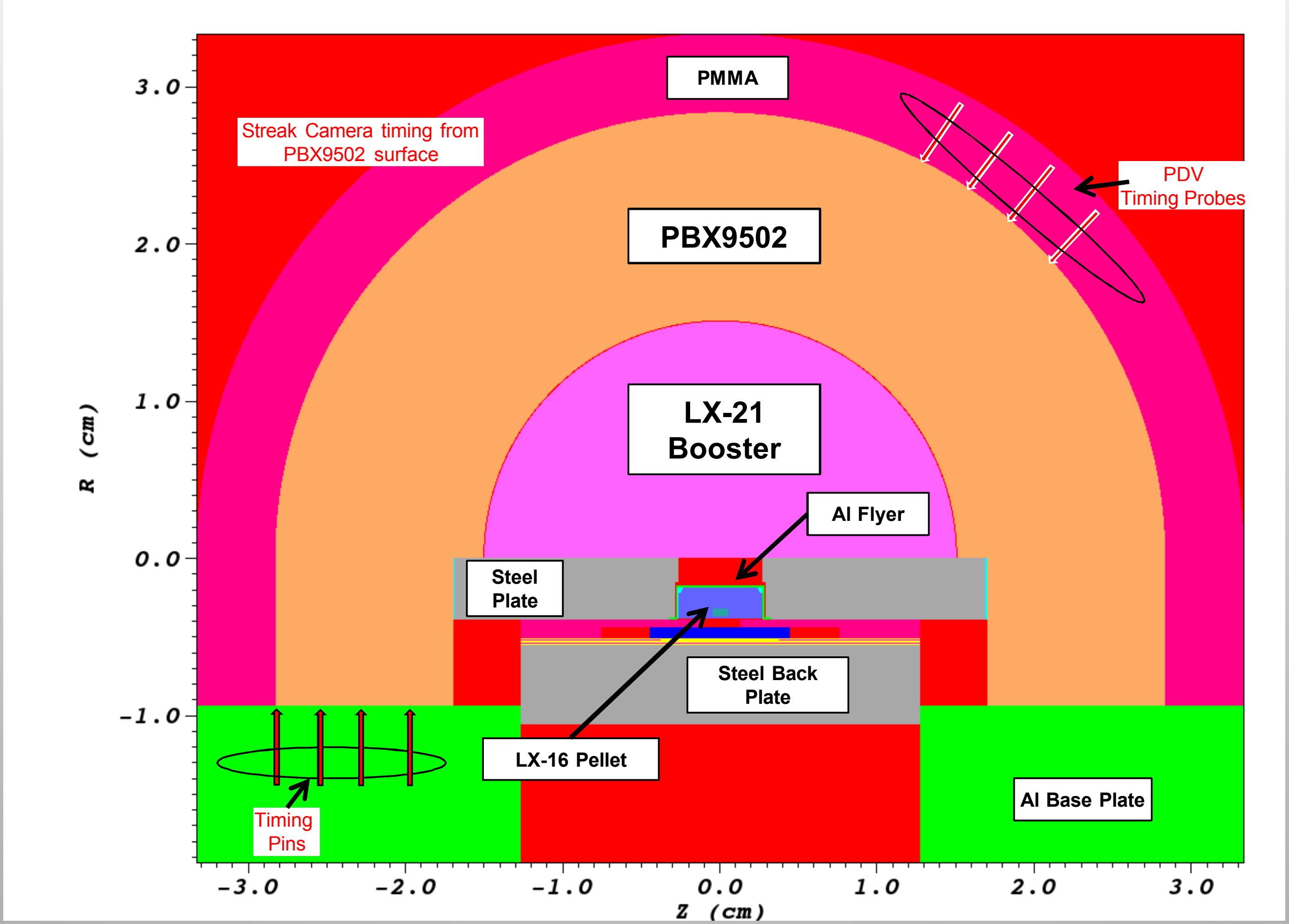
Transferred under auspices of the US/UK MDA, JOWOG 09 per DOE/NNSA NAP-23

LLNL-PRES-XXXXXX

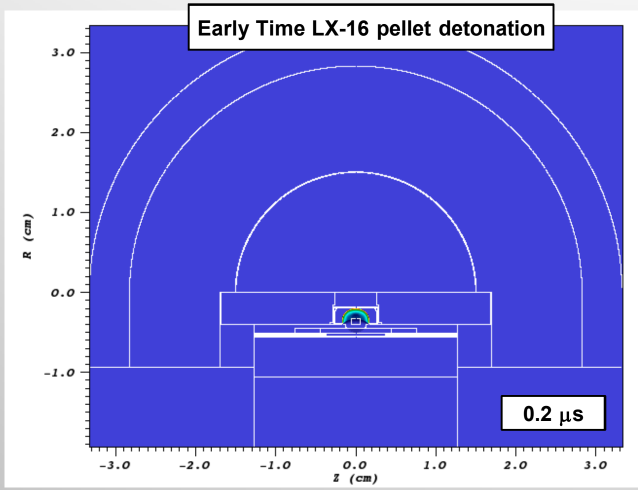
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

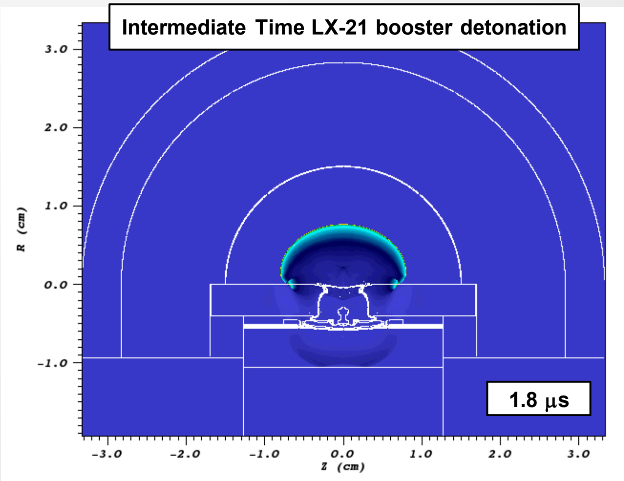
Unclassified

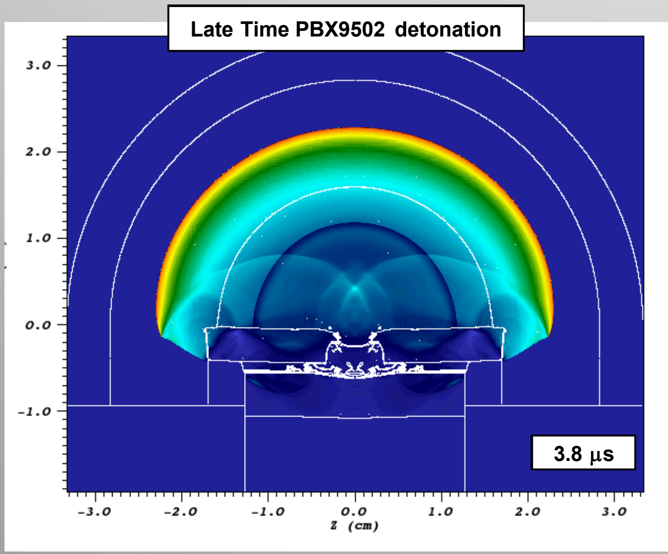
Simulation Setup of PBX9502/LX-21 Snowball with Initiation Assembly



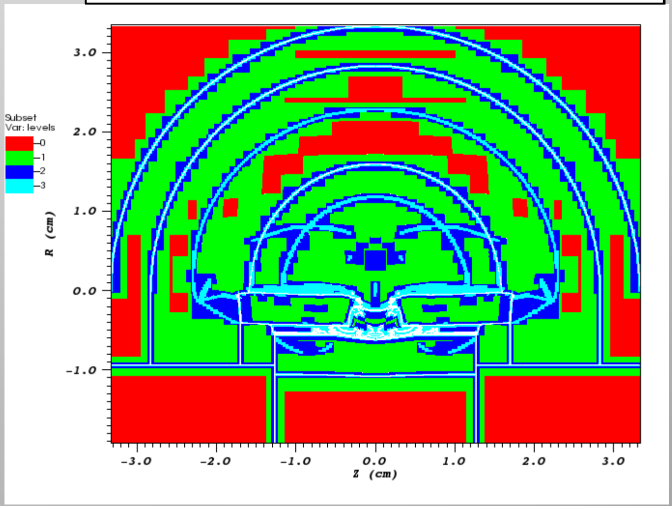
Reactive Flow HE detonation modeling was used from the LX-16 pellet to the PBX9502 dome







Adaptive Mesh Refinement used with levels 0, 1, 2, 3 at 30, 90, 270, 810 zones/cm



PBX9502 Modeling Requirements

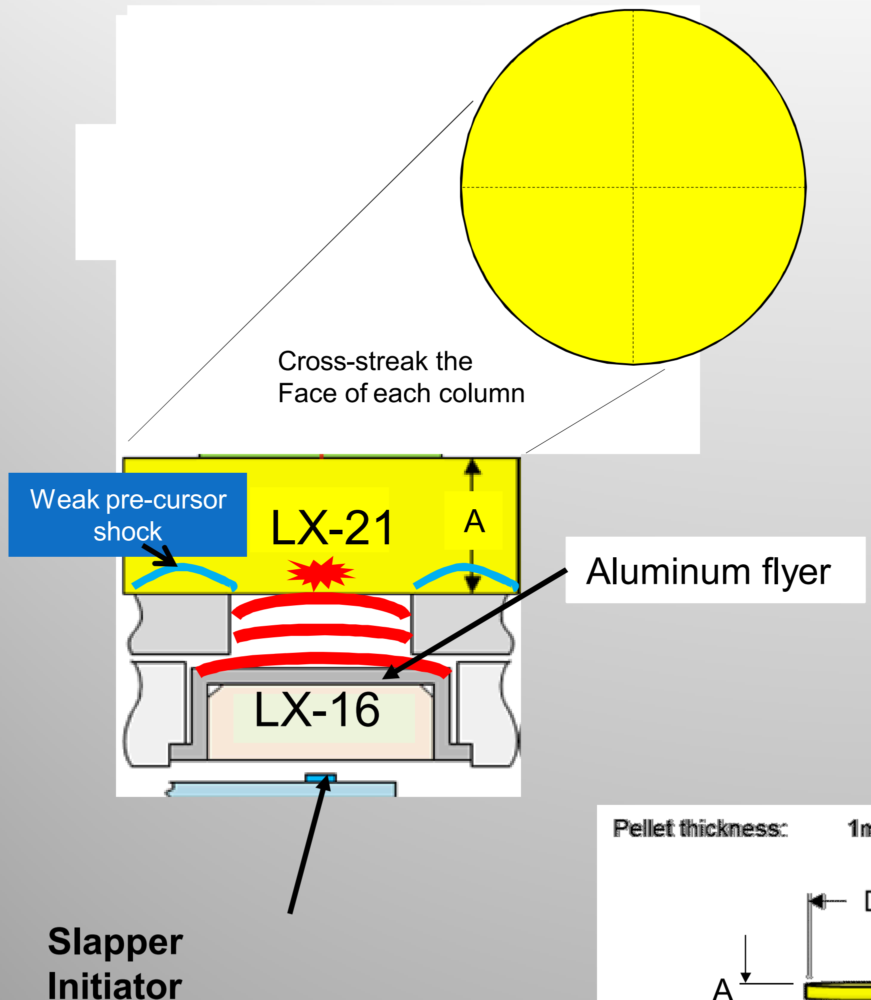
- For insensitive explosives, such as PBX 9502, chemical reaction time scales can be comparable to flow time scales, leading to non-linear coupling between hydrodynamics and chemistry.
- Because of the relatively slow reaction time scale PBX 9502 detonation velocity varies significantly not only for transient flow but also for steady flow at different part sizes of interest (~ several cms).
- PBX 9502 detonations do not propagate well around corners well leading to corner turning dead zones.
- Dead zones in PBX 9502 can also be cause by de-sensitization by a weak pre-shock of a few GPa.
- A good predictive detonation model should be able to reproduce these and other observed phenomena of interest.
- Reactive Flow models that treat the burning of the un-reacted HE to its products provides the most accurate treatment of detonation physics.
- To provide a self-consistent Reactive Flow detonation model we have coupled the thermo-chemistry CHEETAH EOS and Kinetics code to 3D ALE codes.
- The goal is a predictive model which can be use to predict new formulation PBX 9502 detonation energy delivery for systems of interest.

PBX9502/LX-21 Snowball Model

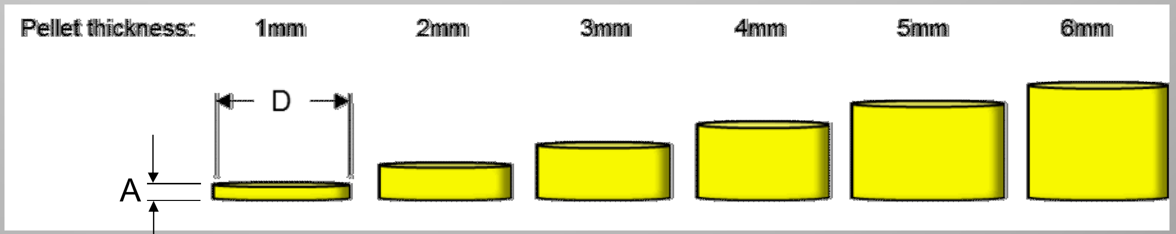
- Our simulation model of the PBX9502 snowball used a reactive flow treatment for the PBX9502 main charge, the LX-21 booster, and the LX-16 initiation system.
- Rates for these explosives were carefully calibrated to accurately model detonation properties.
- For calibration/validation of our model a number of experiments provided explosive energy and burn rate information.
  - PBX9502 (95% TATB, 5% Kelf)
    - Bare rate-sticks at different radii used for size-effect detonation velocity for HE burn rate.
    - Copper cylinders at different radii used for size-effect detonation velocity and long time-scale (10s of μs) side wall velocity for energy.
    - DAX used for detonation velocity and short time-scale (a few μs) directly driven foil velocity energy for energy and HE burn rate.
    - Corner turning experiments including the PANTEX corner turning experiments and snowball experiments used for HE burn rate.
    - Double shock experiments used for HE de-sensitization rate.
  - LX-21(94% LLM-105, 6% Viton)
    - Bare booster breakout experiments used for corner turning for HE burn rate.
    - Copper cylinders detonation velocity, breakout timing and long time-scale (10s of μs) side wall velocity used for energy and HE burn rate.
    - DAX used for detonation velocity and short time-scale (a few μs) directly driven foil velocity energy used for energy and HE burn rate.
    - “Cut-back” booster experiments used for HE burn rate and de-sensitization rate.
  - LX-16 Aluminum flyer velocity and breakout timing used for pellet initiation timing.
- These experiments cover a wide range of different regions of the phase space for detonation waves and calibrations were used that agree with all of the data.

"Cut-back" *experiments* were used to study the early stage propagation and corner turning of a LX-21 detonation wave

(Dan Phillips, Chadd May, Jerry Benterou and Don Hanson)



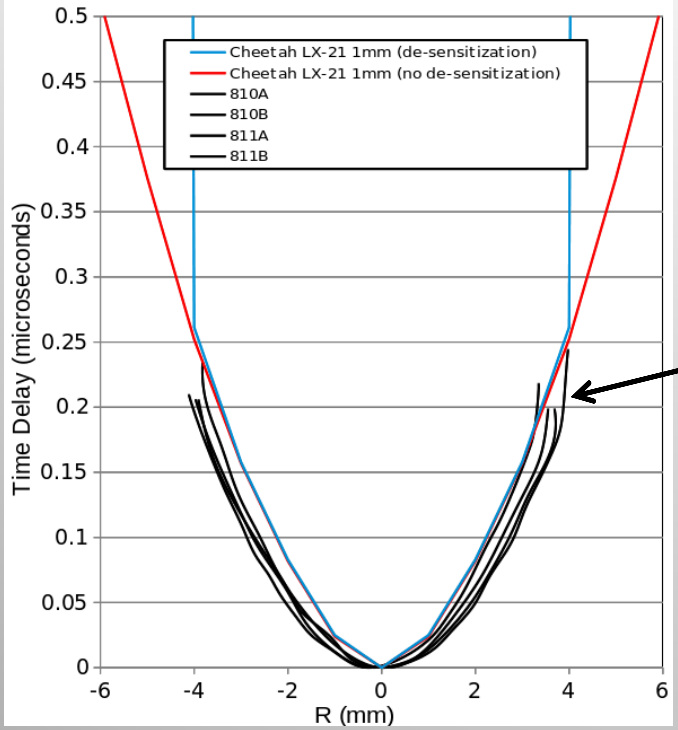
- Cut-back tests were used to measure the breakout profile at several different pellet thicknesses
- Each thickness provides a snapshot of the evolution detonation wave
- The detonation was initiated using a the same LX-16 pellet used for boosters and snowballs.



(D = 19.05 mm)

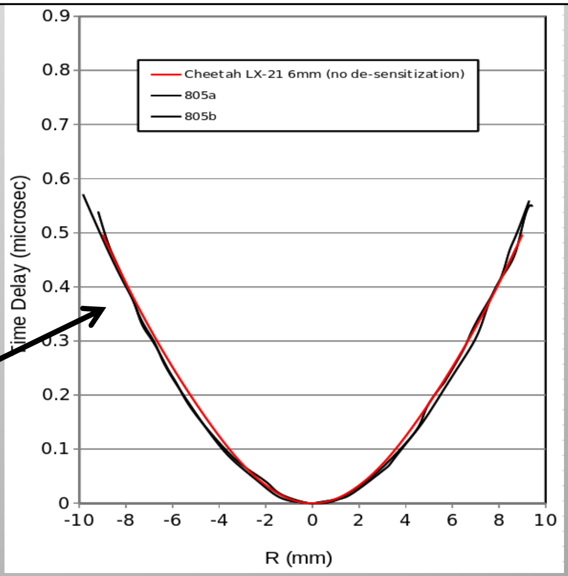
Comparisons with Cheetah for the LX-21 cutback disks show evidence for de-sensitization close to al flyer

Breakout for 1 mm thick disk



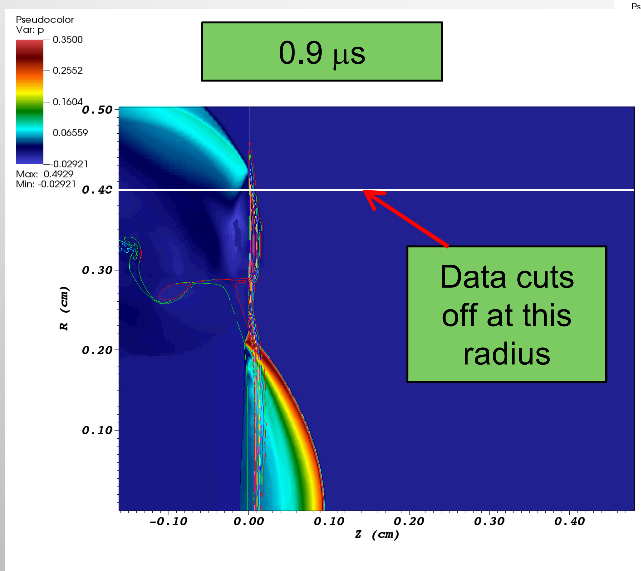
- The 1mm data shows breakout data stops well before the radial ~9.5 mm edge of the disk.
- Simulations show a weak pre-cursor shock passes through the LX-21 close to the MSAD and could de-sensitize the LX-21.
- The thin disk detonation must pass through the pre-shocked region.
- Cheetah model requires a de-sensitization term to match the experimental data.

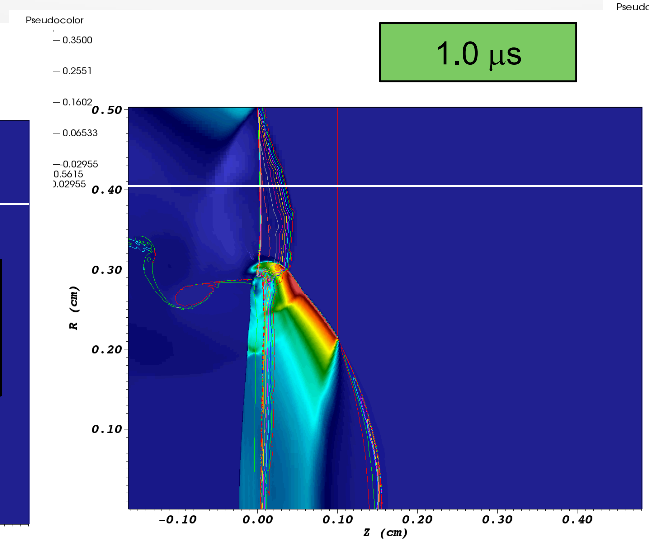
Breakout for 6 mm thick disk

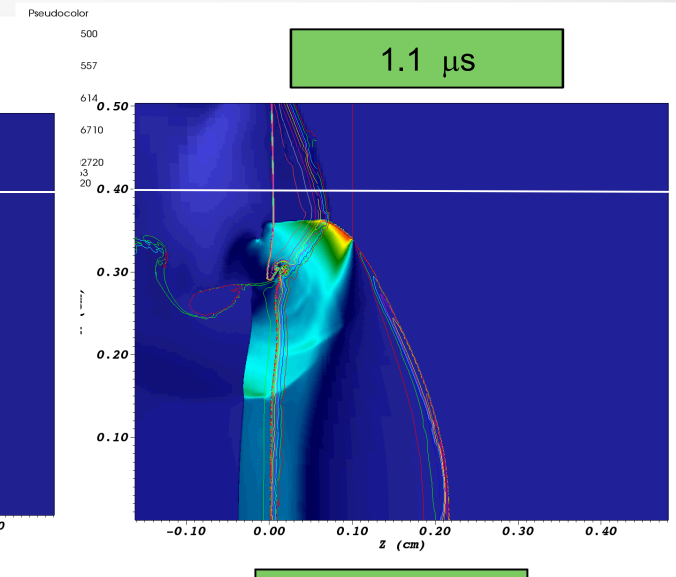


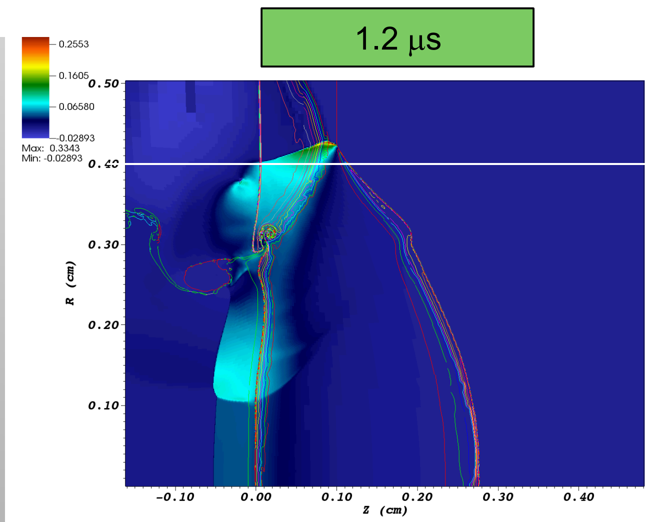
- 6mm thick disk detonation data does not go through the pre-shocked region and shows continuous timing delay at all radii.
- Cheetah model does not need de-sensitization for the thick disks.

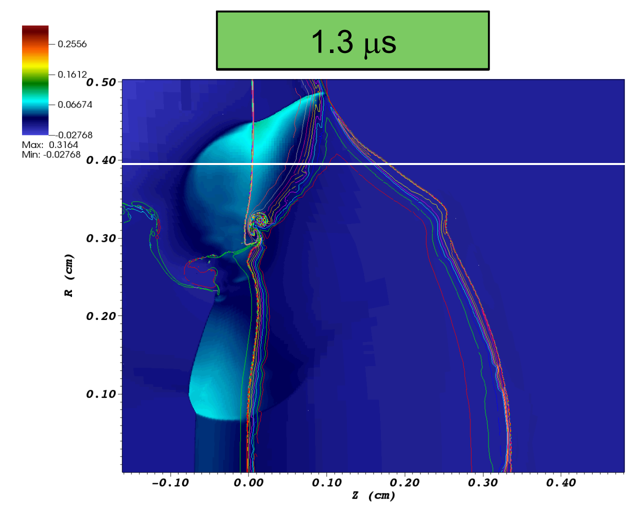
To get agreement with the 1 mm cut-back experiment the LX-21 detonation must fail by 4mm in radius







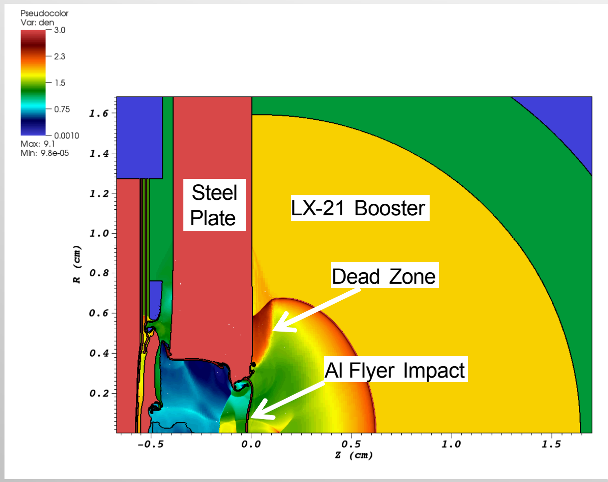




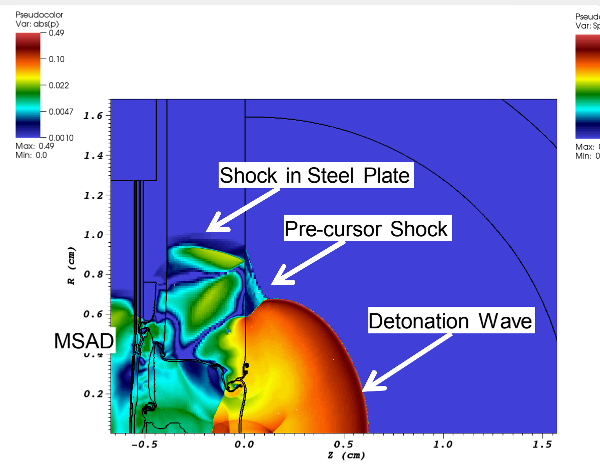
De-sensitization from the weak precursor pre-shock through the steel is needed to kill the LX-21 detonation.

Cheetah simulation of the LX-21 Booster

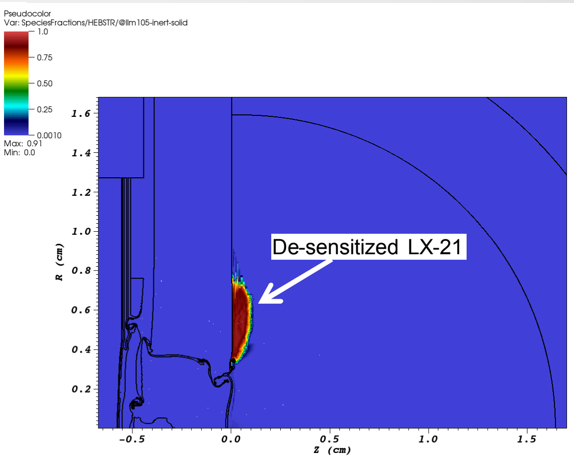
Density Profile



Log abs(Pressure) Profile

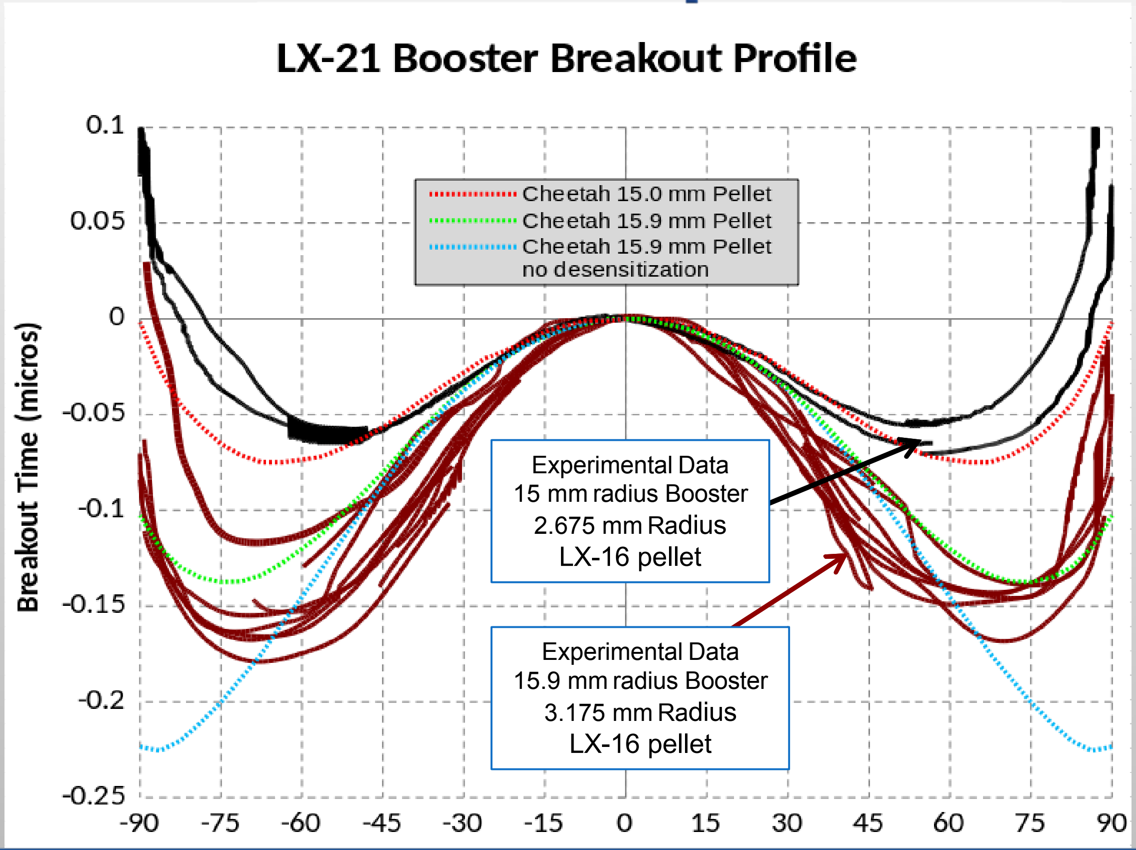


De-sensitized LX-21 Mass Fraction Profile



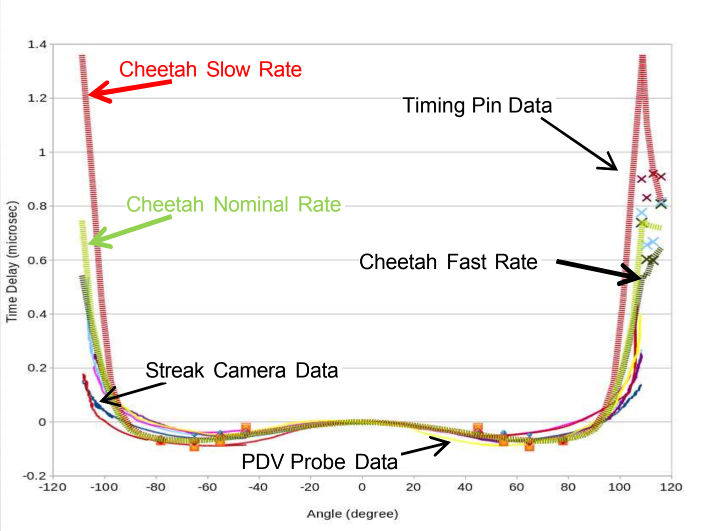
- The Cheetah model includes de-sensitization of the booster HE
- The detonation must burn around the de-sensitized region creating a dead zone.
- Burning around the dead zone strongly modifies the simulation breakout timing as shown in the next figure.

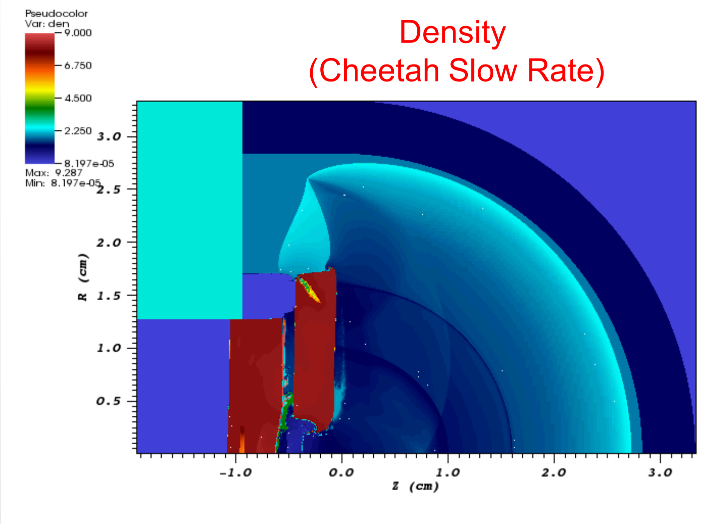
LX-21 booster model breakout timing agrees with data two pellet and flyer radii

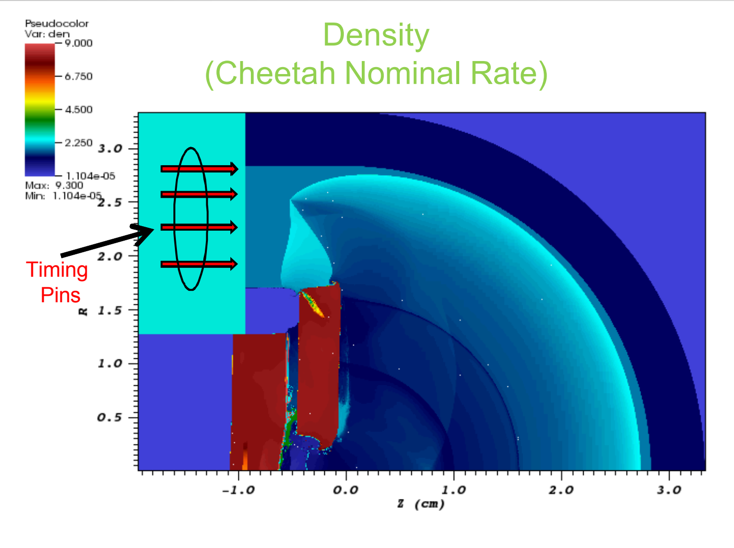


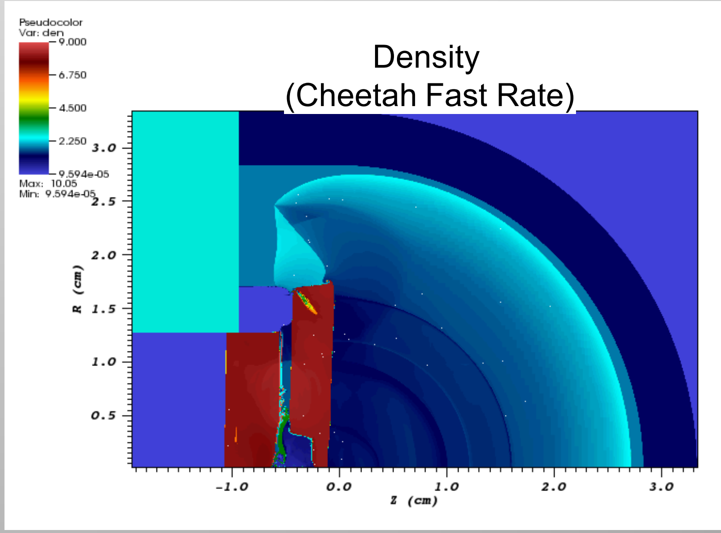
- The Cheetah LX-21 model was calibrated for the geometry of the lower data set.
- It shows that the changes in the LX-16 pellet and al flyer radii were the cause of the upwards shift in the breakout timing of the upper data set.

Calibrated Cheetah Rate agrees with pin, PDV, and streak camera (-90 / 90 degrees) timing data

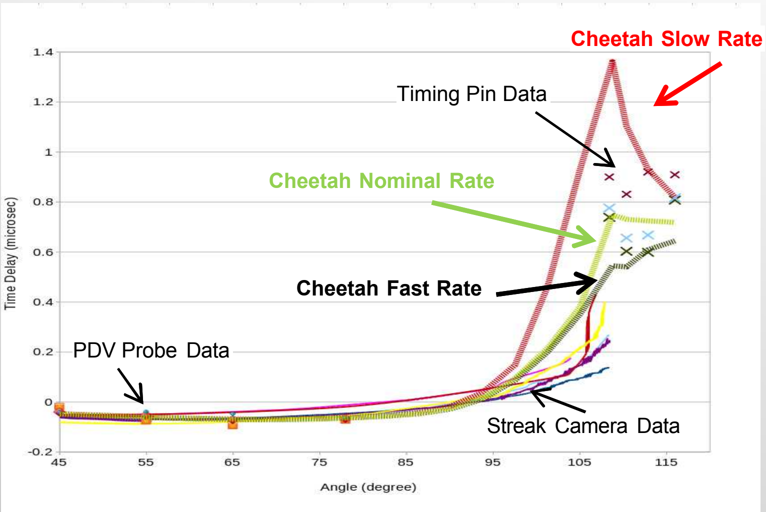


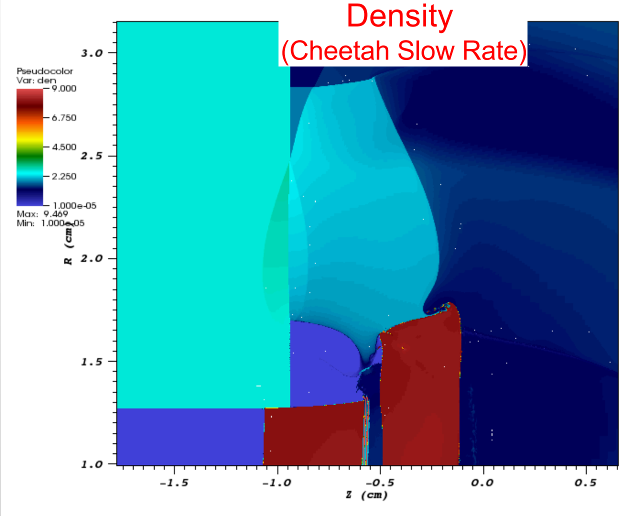


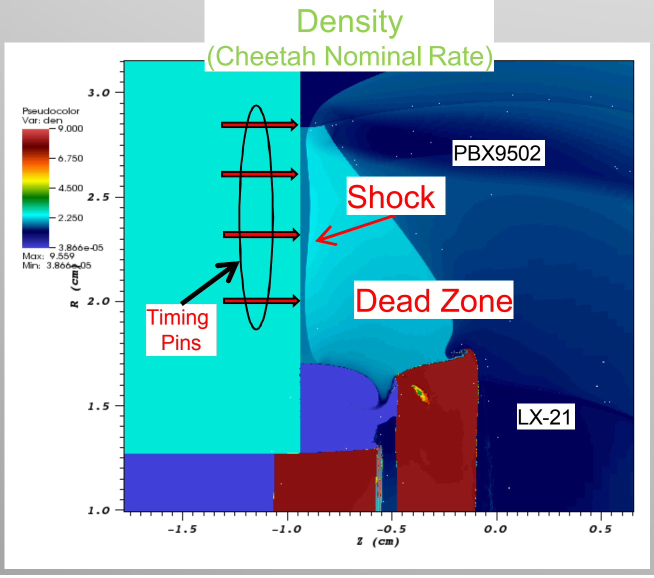


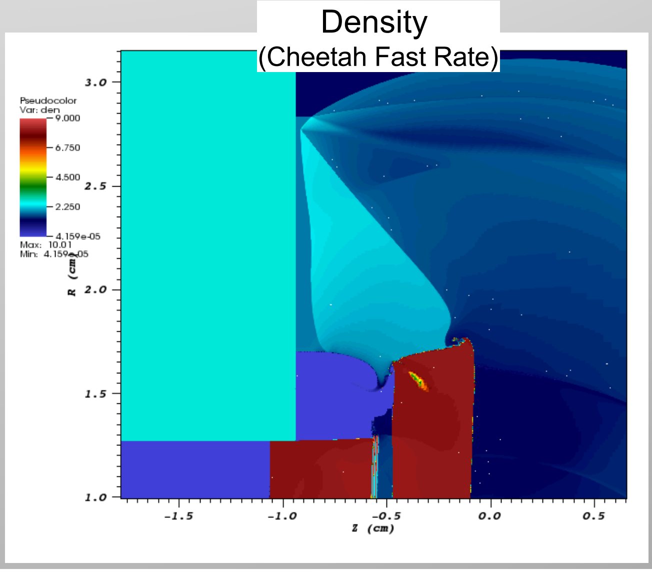


Timing behavior at the timing pins is very sensitive to the dead zone shock arrival time

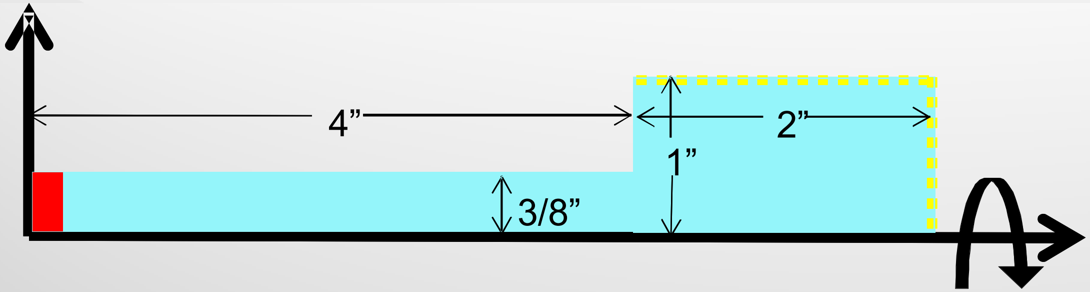


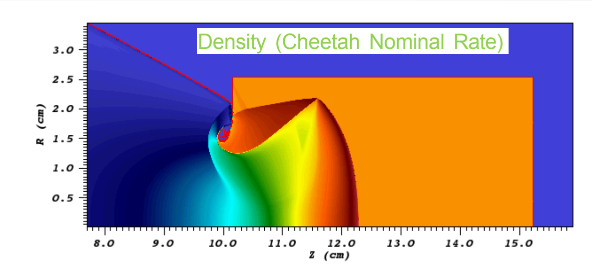




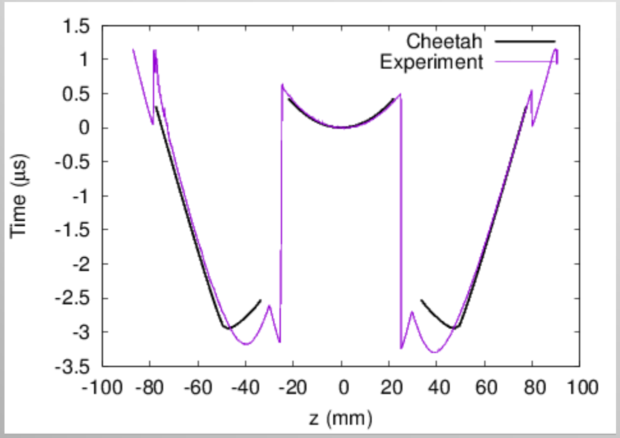


PBX9502 PANTEX Corner Turning is less sensitive to the rate model than the Snowball timing pins

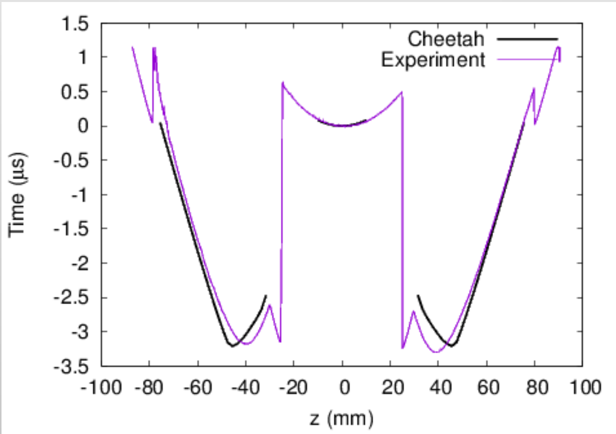




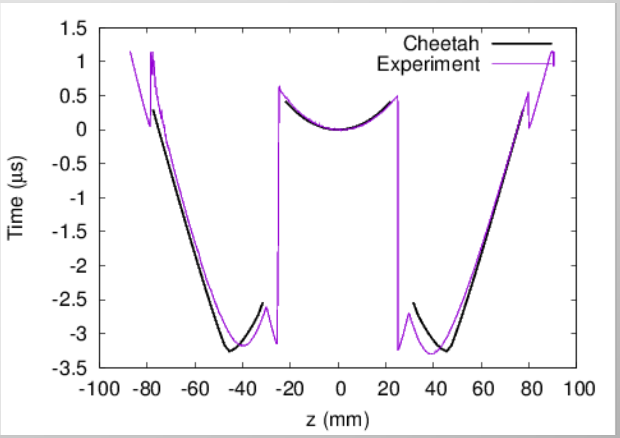
Cheetah Slow Rate



Cheetah Nominal Rate



Cheetah Fast Rate



- Breakout position and shape varies only slightly for the three rate models.
- This is due to differences in the experimental geometry.
- For the PANTEX experiment the dead zone shock strongly lags the detonation breakout.

Conclusions

- Reactive flow modeling can accurately capture booster initiation and snowball corner turning behavior.
- After detailed calibration we were able to model the PBX9502 / LX-21 snowball and to show sensitivity in the breakout timing to initiation geometry and rate changes.
- Snowball pin timing data at large angles can show more rate sensitivity that Pantex corner turning experiments.
- We plan on using this model to predict sensitivity to density, contaminants, and binders for new experiments using LLM-105 and TATB based explosives.
- This will require adequate rate and energy data for the explosives of interest.